Attachment I (1 of 5)

Marks'
Standard Handbook for Mechanical Engineers

Revised by a staff of specialists

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Table 12b. Alloy-Steel Compositions[a,b,c,d]

AISI No.	Chemical composition limits (ladle analyses), %[c,d] C	Mn	P, max	S, max	Si	Ni	Cr	Mo	V
1330	0.28–0.33	1.60–1.90	0.035	0.040	0.20–0.35				
1335	0.33–0.38	1.60–1.90	0.035	0.040	0.20–0.35				
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.20–0.35				
1345	0.43–0.48	1.60–1.90	0.035	0.040	0.20–0.35				
4012	0.09–0.14	0.75–1.00	0.035	0.040	0.20–0.35			0.15–0.25	
4023	0.20–0.25	0.70–0.90	0.035	0.040	0.20–0.35			0.20–0.30	
4024	0.20–0.25	0.70–0.90	0.035	0.035–0.050	0.20–0.35			0.20–0.30	
4027	0.25–0.30	0.70–0.90	0.035	0.040	0.20–0.35			0.20–0.30	
4028	0.25–0.30	0.70–0.90	0.035	0.035–0.050	0.20–0.35			0.20–0.30	
4037	0.35–0.40	0.70–0.90	0.035	0.040	0.20–0.35			0.20–0.30	
4047	0.45–0.50	0.70–0.90	0.035	0.040	0.20–0.35			0.20–0.30	
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.20–0.35		0.40–0.60	0.08–0.15	
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.20–0.35		0.80–1.10	0.15–0.25	
4137	0.35–0.40	0.70–0.90	0.035	0.040	0.20–0.35		0.80–1.10	0.15–0.25	
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.20–0.35		0.80–1.10	0.15–0.25	
4142	0.40–0.45	0.75–1.00	0.035	0.040	0.20–0.35		0.80–1.10	0.15–0.25	
4145	0.43–0.48	0.75–1.00	0.035	0.040	0.20–0.35		0.80–1.10	0.15–0.25	
4147	0.45–0.50	0.75–1.00	0.035	0.040	0.20–0.35		0.80–1.10	0.15–0.25	
4150	0.48–0.53	0.75–1.00	0.035	0.040	0.20–0.35		0.80–1.10	0.15–0.25	
4320	0.17–0.22	0.45–0.65	0.035	0.040	0.20–0.35	1.65–2.00	0.40–0.60	0.20–0.30	
4340	0.38–0.43	0.60–0.80	0.035	0.040	0.20–0.35	1.65–2.00	0.70–0.90	0.20–0.30	
E4340[e]	0.38–0.43	0.65–0.85	0.025	0.025	0.20–0.35	1.65–2.00	0.70–0.90	0.20–0.30	
4419	0.18–0.23	0.45–0.65	0.035	0.040	0.20–0.35			0.45–0.60	
4615	0.13–0.18	0.45–0.65	0.035	0.040	0.20–0.35	1.65–2.00		0.20–0.30	
4620	0.17–0.22	0.45–0.65	0.035	0.040	0.20–0.35	1.65–2.00		0.20–0.30	
4621	0.18–0.23	0.70–0.90	0.035	0.040	0.20–0.35	1.65–2.00		0.20–0.30	
4626	0.24–0.29	0.45–0.65	0.035	0.040	0.20–0.35	0.70–1.00		0.15–0.25	
4718	0.16–0.21	0.70–0.90				0.90–1.20	0.35–0.55	0.30–0.40	
4720	0.17–0.22	0.50–0.70	0.035	0.040	0.20–0.35	0.90–1.20	0.35–0.55	0.15–0.25	
4815	0.13–0.18	0.40–0.60	0.035	0.040	0.20–0.35	3.25–3.75		0.20–0.30	
4817	0.15–0.20	0.40–0.60	0.035	0.040	0.20–0.35	3.25–3.75		0.20–0.30	
4820	0.18–0.23	0.50–0.70	0.035	0.040	0.20–0.35	3.25–3.75		0.20–0.30	
5015	0.12–0.17	0.30–0.50	0.035	0.040	0.20–0.35		0.30–0.50		
50B44[f]	0.43–0.48	0.75–1.00	0.035	0.040	0.20–0.35		0.40–0.60		
50B46[f]	0.44–0.49	0.75–1.00	0.035	0.040	0.20–0.35		0.20–0.35		
50B50[f]	0.48–0.53	0.75–1.00	0.035	0.040	0.20–0.35		0.40–0.60		
50B60[f]	0.56–0.64	0.75–1.00	0.035	0.040	0.20–0.35		0.40–0.60		
5120	0.17–0.22	0.70–0.90	0.035	0.040	0.20–0.35		0.70–0.90		
5130	0.28–0.33	0.70–0.90	0.035	0.040	0.20–0.35		0.80–1.10		
5132	0.30–0.35	0.60–0.80	0.035	0.040	0.20–0.35		0.75–1.00		
5135	0.33–0.38	0.60–0.80	0.035	0.040	0.20–0.35		0.80–1.05		
5145	0.43–0.48	0.70–0.90	0.035	0.040	0.20–0.35		0.70–0.90		
5147	0.46–0.51	0.70–0.95	0.035	0.040	0.20–0.35		0.85–1.15		
5150	0.48–0.53	0.70–0.90	0.035	0.040	0.20–0.35		0.70–0.90		
5155	0.51–0.59	0.70–0.90	0.035	0.040	0.20–0.35		0.70–0.90		
5160	0.56–0.64	0.75–1.00	0.035	0.040	0.20–0.35		0.70–0.90		
51B60[f]	0.56–0.64	0.75–1.00	0.035	0.040	0.20–0.35		0.70–0.90		
E51100[e]	0.98–1.10	0.25–0.45	0.025	0.025	0.20–0.35		0.90–1.15		
E52100[e]	0.98–1.10	0.25–0.45	0.025	0.025	0.20–0.35		1.30–1.60		
6118	0.16–0.21	0.50–0.70	0.035	0.040	0.20–0.35		0.50–0.70		0.10–0.15
6150	0.48–0.53	0.70–0.90	0.035	0.040	0.20–0.35		0.80–1.10		0.15
81B45[f]	0.43–0.48	0.75–1.00	0.035	0.040	0.20–0.35	0.20–0.40	0.35–0.55	0.08–0.15	
8615	0.13–0.18	0.70–0.90	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8617	0.15–0.20	0.70–0.90	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8620	0.18–0.23	0.70–0.90	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8622	0.20–0.25	0.70–0.90	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8625	0.23–0.28	0.70–0.90	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8627	0.25–0.30	0.70–0.90	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8637	0.35–0.40	0.75–1.00	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	

AISI No.	Chemical composition limits (ladle analyses), %[c,d]								
	C	Mn	P, max	S, max	Si	Ni	Cr	Mo	V
8640	0.38–0.43	0.75–1.00	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8642	0.40–0.45	0.75–1.00	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8645	0.43–0.48	0.75–1.00	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8655	0.51–0.59	0.75–1.00	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.15–0.25	
8720	0.18–0.23	0.70–0.90	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.20–0.30	
8740	0.38–0.43	0.75–1.00	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.20–0.30	
8822	0.20–0.25	0.75–1.00	0.035	0.040	0.20–0.35	0.40–0.70	0.40–0.60	0.30–0.40	
9255	0.51–0.59	0.70–0.95	0.035	0.040	1.80–2.20				
9260	0.56–0.64	0.75–1.00	0.035	0.040	1.80–2.20				
94B17[f]	0.15–0.20	0.75–1.00	0.035	0.040	0.20–0.35	0.30–0.60	0.30–0.50	0.08–0.15	
94B30[f]	0.28–0.33	0.75–1.00	0.035	0.040	0.20–0.35	0.30–0.60	0.30–0.50	0.08–0.15	

[a]These tables are subject to change from time to time, with new steels sometimes added, other steels eliminated, and compositions of retained steels occasionally altered. Current publications of AISI and SAE should be consulted for latest information.

[b]Applicable to blooms, billets, slabs, and hot-rolled and cold-rolled bars.

[c]These steels may be produced by the basic oxygen, basic open-hearth, or basic electric steelmaking process.

[d]Small quantities of certain elements which are not specified or required may be found in alloy steels. These elements are considered to be incidental and are acceptable up to the following maximum amounts: copper to 0.35 percent, nickel to 0.25 percent, chromium to 0.20 percent, and molybdenum to 0.06 percent.

[e]Electric-furnace steel.

[f]Boron content is 0.0005 percent minimum.

machinability, **lead** is added to steel. The usual range is from 0.20 to 0.35 percent lead.

Cold-finished carbon-steel bars are used for bolts, nuts, typewriter and cash-register parts, motor and transmission power shafting, piston pins, bushings, oil-pump shafts and gears, etc. Average mechanical properties of cold-drawn steel are given in Table 15. Besides improved mechanical properties, cold-finished steel has better machining properties than hot-rolled products. The surface finish and dimensional accuracy are also greatly improved by cold finishing.

Forging steels, between 0.30 and 0.40 percent carbon, are used for axles, bolts, pins, connecting rods, and similar applications. These steels are readily forged and, after heat treatment, develop considerably higher mechanical properties than low-carbon steels. For heavy sections where high strength is required, such as in crankshafts and heavy-duty gears, the carbon may be increased to 0.40 to 0.50 percent and sufficient alloy content used to obtain the necessary hardenability.

TOOL STEELS

The application of tool steels can generally be fitted into one of the following categories or types of operations: cutting, shearing, forming, drawing, extruding, rolling, and battering. Each of these operations requires in the tool steel a particular physical property or a combination of such metallurgical characteristics as hardness, strength, toughness, wear resistance, and resistance to heat softening, before optimum performance can be realized. These considerations are of prime importance in tool selection; but hardenability, permissible distortion, surface decarburization during heat treatment, and machinability of the tool steel are a few of the additional factors to be weighed in reaching a final decision. In actual practice, the final selection of a tool steel represents a compromise of the most desirable physical properties with the best overall economic performance. Tool steels have been identified and classified by the SAE and the AISI into six major groups, based upon quenching methods, applications, special characteristics, and use in specific industries. These six classes are water-hardening, shock-resisting, cold-work, hot-work, high-speed, and special-purpose tool steels. A simplified classification of these six basic types and their subdivisions is given in Table 16.

Water-hardening tool steels, containing 0.60 to 1.40 percent carbon, are widely used because of their low cost, good toughness, and excellent machinability. They are shallow-hardening steels, unsuitable for nondeforming applications because of high warpage, and possess poor resistance to softening at elevated temperatures. Water-hardening tool steels have the widest applications of all major groups and are used for files, twist drills, shear knives, chisels, hammers, and forging dies.

Shock-resisting tool steels, with chromium-tungsten, silicon-molybdenum, or silicon-manganese as the dominant alloys, combine good hardenability with outstanding toughness. A tendency to distort easily is their greatest disadvantage. However, oil quenching can minimize this characteristic.

Cold-work tool steels are divided into three groups: oil-hardening, medium-alloy air-hardening, and high-carbon, high-chromium. In general, this class possesses high wear resistance and hardenability, develops little distortion, but at best is only average in toughness and in resistance to heat softening. Machinability ranges from good in the oil-hardening grade to poor in the high-carbon, high-chromium steels.

Hot-work tool steels are either chromium- or tungsten-based alloys possessing fine nondeforming, hardenability, toughness, and resistance to heat-softening characteristics, with fair machinability and wear resistance. Either air or oil hardening can be employed. Applications are blanking, forming, extrusion and casting dies where temperatures may rise to 540°C (1000°F).

High-speed tool steels, the best-known tool steels, possess the best combination of all properties excepting toughness, which is not critical for high-speed cutting operations, and are either tungsten- or molybdenum-base types. Cobalt is added in some cases to improve the cutting qualities in roughing operations. They retain considerable hardness at a red heat. Very high heating temperatures are required for the heat treatment of

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(4 of 5)

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19). These alloys
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ly resistant to hot
to intergranular
the grain bound-
d exposure in the
e range. Normal
ng the steel above
itanium or colum-
es 321 and 347,
to this intergranu-
a carbon content
to minimize the
excellent applica-
postannealing is

AISI type no.	C	Mn, max	Si, max	Cr	Ni	Other[a]
				Nominal composition, %		
Austenitic steels						
201	0.15 max	7.50[b]	1.00	16.00–18.00	3.50–5.50	0.25 max N
202	0.15 max	10.00[c]	1.00	17.00–19.00	4.00–6.00	0.25 max N
301	0.15 max	2.00	1.00	16.00–18.00	6.00–8.00	
302	0.15 max	2.00	1.00	17.00–19.00	8.00–10.00	
302B	0.15 max	2.00	3.00[d]	17.00–19.00	8.00–10.00	
303	0.15 max	2.00	1.00	17.00–19.00	8.00–10.00	0.15 min S[f]
303 (Se)	0.15 max	2.00	1.00	17.00–19.00	8.00–10.00	0.15 min Se
304	0.08 max	2.00	1.00	18.00–20.00	8.00–10.50	
304L	0.03 max	2.00	1.00	18.00–20.00	8.00–12.00	
305	0.12 max	2.00	1.00	17.00–19.00	10.50–13.00	
308	0.08 max	2.00	1.00	19.00–21.00	10.00–12.00	
309	0.20 max	2.00	1.00	22.00–24.00	12.00–15.00	
309S	0.08 max	2.00	1.00	22.00–24.00	12.00–15.00	
310	0.25 max	2.00	1.50	24.00–26.00	19.00–22.00	
310S	0.08 max	2.00	1.50	24.00–26.00	19.00–22.00	
314	0.25 max	2.00	3.00[e]	23.00–26.00	19.00–22.00	
316	0.08 max	2.00	1.00	16.00–18.00	10.00–14.00	2.00–3.00 Mo
316L	0.03 max	2.00	1.00	16.00–18.00	10.00–14.00	2.00–3.00 Mo
317	0.08 max	2.00	1.00	18.00–20.00	11.00–15.00	3.00–4.00 Mo
321	0.08 max	2.00	1.00	17.00–19.00	9.00–12.00	5 × C min Ti
347	0.08 max	2.00	1.00	17.00–19.00	9.00–12.00	10 × C min Cb-Ta
348	0.08 max	2.00	1.00	17.00–19.00	9.00–13.00	10 × C min Cb-Ta (0.10 max Ta), 0.20 Co
Martensitic steels						
403	0.15 max	1.00	0.50	11.50–13.00		
410	0.15 max	1.00	1.00	11.50–13.50		
414	0.15 max	1.00	1.00	11.50–13.50	1.25–2.50	
416	0.15 max	1.25	1.00	12.00–14.00		0.15 minS[f]
416 (Se)	0.15 max	1.25	1.00	12.00–14.00		0.15 min Se
420	0.15 min	1.00	1.00	12.00–14.00		
420F	0.15 min	1.25	1.00	12.00–14.00		0.15 min S[f]
431	0.20 max	1.00	1.00	15.00–17.00	1.25–2.50	
440A	0.60–0.75	1.00	1.00	16.00–18.00		0.75 max Mo
440B	0.75–0.95	1.00	1.00	16.00–18.00		0.75 max Mo
440C	0.95–1.20	1.00	1.00	16.00–18.00		0.75 max Mo
501	0.10 min	1.00	1.00	4.00–6.00		0.40–0.65 Mo
Ferritic steels						
405	0.08 max	1.00	1.00	11.50–14.50		0.10–0.30 Al
429	0.12 max	1.00	1.00	14.00–16.00		
430	0.12 max	1.00	1.00	16.00–18.00		
430F	0.12 max	1.25	1.00	16.00–18.00		0.15 min S
430F (Se)	0.12 max	1.25	1.00	16.00–18.00		0.15 min Se
434, 436	0.12 max	1.00	1.00	16.00–18.00		0.75–1.25 Mo[g]
442	0.20 max	1.00	1.00	18.00–23.00		
446	0.20 max	1.50	1.00	23.00–27.00		0.25 max N
502	0.10 max	1.00	1.00	4.00–6.00		0.40–0.65 Mo

[a]Other elements in addition to those shown below are as follows: phosphorus is 0.20 percent max in types 303 and 303 (Se); 0.06 percent max in type 201, 202, 416, 416 (Se), 420F, 430F, 430F (Se); 0.045 max in types 301, 302, 302B, 304, 304L, 305, 308, 309, 309S, 310, 310S, 314, 316, 316L, 317, 321, 347, 348; 0.040 percent max in types 403, 405, 410, 414, 420, 420F, 429, 430, 431, 434, 436, 440A, 440B, 440C, 442, 446. Sulfur is 0.030 percent max in types 201, 202, 301, 302, 302B, 304, 304L, 305, 308, 309, 309S, 310, 310S, 314, 316, 316L, 317, 321, 347, 348, 403, 405, 410, 414, 420, 429, 430, 431, 434, 440A, 440B, 440C, 442, 446, 501, and 502; 0.060 percent max in 303 (Se), 416 (Se), 430F, and 430F (Se); 0.15 percent min in type 303, 416, 420F, and 430F.

[b]Mn range, 5.50–7.50.

[c]Mn range 7.50–10.00.

[d]Si range 2.00–3.00.

[e]Si range 1.50–3.00.

[f]Mo 0.60 (optional).

[g]For 436, 5 × C min Cb-Ta, 0.70 max.

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Table 18b. Typical Compositions of Some Nonstandard Grades of Wrought Stainless Steels

Tentative designation	Composition, %						
	C	Mn	Si	Cr	Ni	Mo	Other
308L	0.025	1.75	0.40	21.00	10.00		
316F	0.06	1.50	0.50	18.00	13.00	2.25	0.13 P, 0.15 S
317L	0.025	1.75	0.50	18.50	13.50	3.25	
329	0.07	0.60	0.50	27.50	4.50	2.25	
18-18-2	0.07	2.00	2.20	19.00	18.50		
418	0.17	0.40	0.30	12.75	2.00		3.00 W
420F	0.38	0.45	0.35	13.50			0.21 Se or 0.18 S
422	0.20	0.65	0.50	12.00	0.75	1.00	1.00 W, 0.30 V
440F	1.00	0.40	0.40	17.00			0.18 Se or 0.08 S
442	0.06	0.50	0.50	21.00			
443	0.06	0.50	0.50	21.00			1.00 Cu
Stainless W	0.07	0.50	0.50	16.75	6.75		0.80 Ti, 0.20 Al
17-4 PH	0.04	0.40	0.50	16.50	4.25		0.25 Cb, 3.60 Cu
17-7 PH	0.07	0.70	0.40	17.00	7.00		1.15 Al
PH 15-7 Mo	0.07	0.70	0.40	15.00	7.00	2.25	1.15 Al
AM-350	0.10	0.75	0.35	16.50	4.25	2.75	0.10 N
AM-355	0.13	0.85	0.35	15.50	4.25	2.75	0.12 N
16-18	0.05	0.50	0.40	16.00	19.00		
20-29 Cu-Mo	0.05	0.75	1.00	20.00	29.00	2.20	3.20 Cu
17-10 P	0.12	0.75	0.50	17.00	10.50		0.28 P
HMN	0.30	3.50	0.50	18.50	9.50		0.25 P
Tenelon	0.08	14.50	0.50	17.00			0.40 N

Group B (Martensitic) The hardenable alloys can be heat-treated to a high hardness and because of their oxidation resistance are used extensively for cutlery, razor blades, surgical and dental instruments, springs for high-temperature operation, ball valves and seats, and similar applications. Compositions and obtainable properties are given in Table 18 and 19, respectively. The hardening-temperature range depends on composition, but in general, the higher the quenching temperature, the harder the article. Oil quenching is preferable, but with thin and intricate shapes, hardening should be obtained by cooling in air. Tempering at 425°C (800°F) does not lower the hardness of the part, and in this condition these steels show remarkable resistance to fruit and vegetable acids, lye, ammonia, and other corrosive agents to which cutlery may be subjected.

Group C (Ferritic) This group is frequently called **stainless iron** because of its low carbon content. The alloys possess considerable ductility, ability to be worked hot or cold, and excellent corrosion resistance and are relatively inexpensive. Although these low-carbon chromium alloys cannot be hardened by heat treatment, they can be hardened to a considerable extent by cold working. Alloys containing 16 to 18 percent Cr are probably the most useful of the straight chromium steels because of their forming and medium-deep-drawing properties. They are used extensively for kitchen equipment, dairy machinery, interior decorative work, automobile trimmings, and chemical equipment (to resist nitric acid corrosion).

For resisting oxidizing conditions at high temperatures, the Cr content is increased to between 25 and 30 percent. These alloys are useful for all types of furnace parts not subjected to high stress. Since the oxidation resistance is independent of carbon content, soft, forgeable alloys low in carbon can be rolled into plates, shapes, and sheets, and hard and wear-resistant castings can be made from higher-carbon, nonforgeable alloys.

The compositions and mechanical properties of the ferritic alloys are given in Tables 18 and 19, respectively.

There are many nonstandard grades of stainless steels developed for specific applications. An important group is the **precipitation-hardening alloys,** which consist essentially of the 18-8 composition to which age-hardening elements such as titanium, columbium, aluminum, copper, and molybdenum have been added. Typical compositions are **stainless W,** with 17 Cr, 7 Ni, 0.70 Ti, and 0.20 Al; **17-7 PH,** with 17 Cr, 7 Ni, and 1.00 Al; and **AM 350,** with 17 Cr, 4 Ni, 3 Mo, and 0.10 N. Typical properties obtained in the 17-7 PH by solution annealing at 760°C (1400°F) and cooling and aging at 565°C (1050°F) are 1,276 MPa (185,000 lb/in^2) yield strength, 1,379 MPa (200,000 lb/in^2) tensile strength, and 9 percent elongation. These precipitation-hardening stainless steels are available in coils, sheets, strip, plate, forging billets, bars, rods, and wire. Because strength does not vary with bar size and can be developed in any thickness, many new applications are feasible. Final-machining operations can be performed before heat treatment if allowance is made for the slight growth that occurs. Wide application is made of these steels by the aircraft industry because of their high strength-weight ratio and strength at elevated temperatures.

SPECIAL-ALLOY STEELS

Iron-Silicon Alloys The principal iron-silicon alloy products of the steel industry are **electrical sheet steels,** which are alloys of iron and silicon with C, Mn, P, and S kept as low as possible. The silicon increases the electrical resistivity of iron and greatly decreases the hysteresis loss; silicon-alloy sheets are used in almost all magnetic circuits where alternating current is used. For transformers, the silicon content is around 5 percent, but in structures subjected to vibration, such as motor armatures, the silicon is usually kept below 4 percent because of the brittleness of high-silicon sheets.